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ENVIRONMENTAL PROTECTION AND RESTORATION ISSUES ARISING FROM MINERAL INDUSTRY ACTIVITIES

Key advances in the development and application of state-of-the-art technologies for minimizing environmental degradation caused by the mining and processing of mineral resources

Report of the Secretary-General

SUMMARY

The present report has been prepared in response to Economic and Social Council resolution 1994/308. The report describes key advances in the development and application of state-of-the-art technologies for minimizing environmental degradation caused by the mining and processing of mineral resources. Special focus is placed on pollution abatement and clean-up technology leading to both improved competitiveness and environmentally sustainable mining practices.

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INTRODUCTION

1. The Economic and Social Council, in its decision 1994/308, and upon recommendation by the Committee on Natural Resources at its second session, held from 22 February to 4 March 1994, requested the Secretary-General to submit to the Committee at its third session a report on key advances in the development and application of state-of-the-art technologies for minimizing environmental degradation caused by mining activities. The Committee recommended that the report include information on the reprocessing of wastes and tailings and the elimination of negative ecological consequences of the past activities of mineral enterprises.

2. This report is part of a continuing assessment of the effects of environmental protection and conservation policies on the mineral sector by the Committee on Natural Resources. The previous report in this field (E/C.7/1994/10), submitted to the Committee at its second session, analysed the effects of environmental policies worldwide on the world mineral industry. Special focus was placed on the relationship between environmental regulation and technological and organizational change leading to both improved competitiveness and environmentally sustainable mining practices. It concluded that pollution prevention policies targeted at different levels of mining and mineral processing firms might better serve their objectives if they were underpinned by technology policy mechanisms and economic instruments.

3. The present report is structured to address the issues requested by the Council. Chapter I illustrates how technological innovation can improve environmental management in the mining industry. It provides some examples of innovative processes and clean-up technologies. It also examines the link between their development and implementation, and the competitive strategies of mining firms. Chapter II explores the factors which drive the development and application of new technologies, and illustrates the broad spectrum of environmental practices among mining firms. The importance of developing environmental management capability as a complement to new technologies is discussed. In chapter III environmental management practices are analysed. Chapter IV closes with conclusions and policy recommendations to promote the adoption and diffusion of state-of-the-art technologies by the United Nations system, through multilateral and bilateral development assistance, by Governments and by the corporate sector.

I. KEY ADVANCES IN THE DEVELOPMENT OF STATE-OF-THE-ART ENVIRONMENTAL TECHNOLOGY

4. This section illustrates how technological innovation can improve environmental management in the mining and minerals industry. In many cases, new processing techniques and clean-up technologies are able to combine gains in productivity and competitiveness with improvements in environmental performance. This section also includes specific examples of such innovative processes and clean-up technologies and the competitive strategy employed by mining firms.

A. Innovation as a response to economic and environmental imperatives

5. The international mining industry has a reputation for technological conservatism, reflecting high capital costs, long lead times in project development, long project life and considerable uncertainty associated with mining investment regimes. The United States Office of Technology Assessment described this as a "tendency to repair, rebuild, and retrofit, rather than replace equipment. Equipment replacement is avoided because of the capital costs, start-up inefficiencies, and mining and processing plan revisions" (OTA, 1988).

6. New economic realities and environmental pressures are forcing mining firms to look to innovation and technological change in order to remain competitive. The global trend towards economic and political liberalization has sparked off a new wave of exploration and project development. Since the beginning of the decade, over 75 countries have changed their mining laws to encourage foreign investment. New mining operations provide an opportunity to invest in state-of-the-art processing technologies from the outset, integrating new production methods with environmental controls to achieve lower cost production. Increasingly comprehensive and stringent environmental regulations, combined with an emerging tendency for credit-lines and insurance to be conditional upon best-practice environmental performance, has led a number of mining companies to invest in the development and/or acquisition of cleaner production techniques.

7. Mining is an extractive industry which generates profits from the development of ore bodies, the spatial extent and geological properties of which are fixed. As a consequence, efficient mining firms will quickly reach the limits of the resource base under conditions of static technology. Innovation is central to sustaining the profitability of existing mines since by reducing production costs, new process techniques enable the profitable extraction and processing of lower-grade and more complex ores. Arguably, oligopoly has stunted technological development in the mining industry, and increasing competition in recent years has reasserted the imperative for technological innovation. Competition has increased due to a proliferation of new market entrants in the 1970s. Further, competition has increased in end-use markets as the result of new materials able to perform similar functions. Moreover, the recession of the 1970s (together with energy price rises) focused corporate attention on cutting costs and improving efficiency.

8. Radical changes in the mining industry have come mainly through State intervention, and the empirical evidence supports the argument that radical technological change in this industry (which is where the greatest gains in productivity and environmental performance are made) come about as the result of State-subsidized research. This is because of the high risk nature of basic research, the long lead-times required for development, and other market failures that justify State intervention in R&D through State grants. Examples of these are the leaching/SX-EW technologies developed from United States Government-backed ion-exchange work on uranium for energy and defence applications and carbon-in-pulp cyanidation, developed by the United States Bureau of Mines and which has been influential in spurring the recent United States gold boom.

9. Unlike the manufacturing and electric power generation industries, the option of changing raw material feedstocks as a means of reducing pollution is not open to mining firms (although chemical reagents are the subject of recent innovation). This means that innovation in beneficiation and processing is the primary means by which the environmental impacts of production can be reduced (Krauss, 1994).

10. There is growing recognition that technological innovation can be stimulated by an environmental regulatory framework in which compliance costs are offset by productivity gains (Warhurst, 1994a). New, clean technological developments are especially attractive to Governments in developing countries since they hold the promise of reducing environmental damage costs while at the same time maintaining the social and economic benefits of mining (e.g. jobs, taxes and royalties). The opportunities for technological leapfrogging through the transfer of innovative production techniques are rapidly expanding as many less developed countries encourage large exploration programmes and liberalize investment regimes while establishing new codes of environmental practice.

B. Technological innovation for source reduction

11. The recent development of cleaner technologies in the mining industry demonstrates a shift away from end-of-pipe pollution control technologies to an attempt to reduce or even eliminate waste through re-engineering of the production process itself. Managerial competence and effective monitoring are also key determinants of a technology's ability to deliver good performance.

12. The non-ferrous industry, a major producer of nickel, copper, zinc and lead from sulphide ores, is also a major emitter of sulphur dioxide (SO_2), and thus contributes to acid rain. The challenge for this smelting industry is to reduce such emissions while continuing to be viable in a very competitive world market. The development of smelting technology illustrates the shift in thinking away from the retrofitting of pollution controls towards the redesign of the production process. Re-engineering of production has improved efficiency and productivity, while reducing environmental damage costs and environmental compliance costs over the long term.

13. The development of cleaner smelters by processes such as flash converting is said to be one of the most significant innovations in mineral processing in recent times. The new smelter and converter complex at Garfield, Utah, United States of America, replaces an existing facility which was able to handle only 60 per cent of the concentrates produced at the Bingham Canyon mine. To meet increasingly stringent state air-quality regulations, the company was faced with a choice of investing US$ 150 million in pollution control technology and being constrained by the existing smelter capacity, or investing US$ 880 million in a new process. The new process increased the capacity of the smelter to handle 100 per cent of the concentrates, thereby eliminating transportation and processing costs associated with the shipment of concentrates to Pacific Rim smelters, and enabled the plant to meet or exceed all existing and anticipated air quality regulations. It is expected that the new plant will reduce operating costs by 53 per cent (Dimock, 1995).

14. The development of oxygen flash-smelting technology is an example of radical technical change necessitated by the exhaustion of possibilities for efficiency improvements in older technologies. The process efficiencies stemming from the application of the technology have not only reduced SO_2 emissions by over 100,000 tons per annum, but have helped to transform the corporations using the oxygen flash smelter into being among the world's lowest cost producers (Warhurst, 1994a).

15. The HIsmelt process is an attempt to directly smelt iron ore in a single stage and consists of a closed molten bath reactor which eliminates the need for a blast furnace, coke ovens and sinter plants. The process has the potential to substantially improve the economics of steelmaking and result in significant environmental improvements.

16. The Isasmelt process, consisting of a patented lance design with oxygen enrichment, was developed for the smelting of copper in the late 1970s. Not only has it reduced coal and oil consumption, decreased fume emissions, and enabled production to be increased up to threefold, but it is also highly versatile. In addition to copper, the process has been applied to lead and, following the licensing in 1990 of the technology to AGIP Australia, it is also applicable to nickel (Mining Magazine, 1990).

C. Improving efficiency and process control

17. A growing body of evidence suggests that a primary means of improving both environmental performance and productivity is to improve process efficiency (Warhurst, 1995; Romm, 1994). Competitive and regulatory pressures have spurred attempts to use materials more productively by, for example, recovering and recycling reagents.

18. A fundamental prerequisite to improving efficiency and environmental performance is a high level of process control. Process control relies on the supply of reliable and real-time information on operational processes, and the capacity to adjust key variables to maintain desired levels of performance. The microelectronics revolution has enabled greater degrees of process control than were formerly possible (Koppel, 1989). Flotation technologies, for example, have been used since the early 1920s, but it was not until the early 1980s that automated control systems became available, which enabled the fine-tuning of the flotation process to optimize its performance. The introduction of an expert system to control reagent use in flotation has reduced reagent use and, as a result of improving the quality of concentrate passing to the smelter, decreased smelter emissions per unit of output (Hoffman, 1994).

19. For example, recovery of gold from refractory ores is typically below 80 per cent using gravity or cyanidation processes without pretreatment to liberate the gold for subsequent cyanidation. Refractory gold ores are those that do not respond well to simple cyanidation without some form of pretreatment. Methods commonly used are roasting, pressure oxidation, and bio-oxidation.

20. Refractory gold ores have received increasing attention in the United States with the discovery that many near-surface oxidized deposits are underlain by large gold-bearing sulphide deposits. Also, development of cost-effective technology for the pretreatment of refractory gold ores is important for improved recovery rates, as gold ore becomes more carbonaceous and sulphidic in nature. The ability to process refractory gold ores allows resources, whose extraction was previously unprofitable, to be economically mined and can provide employment and socio-economic development to the surrounding region (UNEP Industry and Environment, 1995).

D. Hydrometallurgical approaches

21. Hydrometallurgical approaches to avoid noxious gas discharges continue to receive some attention in the industry. Sherritt Gordon's process for leaching zinc concentrates is proving to be the technology of choice worldwide for the expansion of zinc refineries, hence avoiding the need to roast zinc concentrates. The Sherritt Gordon pressure oxidation process for refractory gold ores is also an improvement environmentally, particularly for high arsenic ores. The vaporization of arsenic oxides by roasting is avoided, and the arsenic is fixed in a benign form suitable for disposal.

22. The opportunities for improving efficiency in conventional processes face diminishing returns. The development of lixivants or frother reagents to improve metal recovery, and the optimization of smelting techniques, demonstrate that large gains in efficiency and waste-reduction can be made initially, while the costs of incremental improvements are not necessarily compensated by the returns. The application of bioleaching in the past 15 years provides an example of radical technological change in the mining industry. In addition to having lower capital and operating costs, and being flexible in scale, bioleaching is a potentially cleaner production process for many metals, since it can obviate the need for the energy intensive and traditionally polluting roasting, smelting and refining stages.

23. An alternative bioleaching process is BacTech, used in Australia. The process uses mixed strains of bacteria able to operate at the ambient temperatures (45-50 degrees C) of the Australian desert. Since this obviates the need for cooling the slurry tanks, BacTech has a cost advantage over the BIOX process for which temperatures must be kept relatively low.

24. In the last five years, Gencor has pioneered the bioleaching of nickel sulphides. The BioNIC process provides a means of treating nickel sulphides when the head grade is too low to allow sufficient concentration. It avoids the need to roast ores and provides an effective way of dealing with high levels of impurities, such as arsenic, which currently prevent the development of many nickel sulphide ores.

25. The São Bento Mineracão company offers one of the few examples of a developing-country enterprise which has incorporated improved economic and environmental efficiency into a new leaching operation. It was the first operation in Brazil to fully incorporate autogenous run-of-mine milling and the second worldwide to utilize pressure oxidation technology for the recovery of

gold from a refractory ore body. These technologies doubled its production and at the same time introduced bacterial oxidation to augment the pressure oxidation process.

26. The pressure oxidation process was selected primarily on the grounds of its superior environmental characteristics. Since Brazilian legislation does not allow for the discharge of sulphur above 80 mg/nm^3 into the atmosphere and of arsenic above 0.2 mg/litre into drainage, their recovery and treatment was an essential part of the process.

E. Innovation in clean-up technologies

27. Although many firms are trying to prevent pollution at the source, the legacy of mining, and other industrial activity, has left significant areas of contaminated land. Regulatory pressure has encouraged innovation in the field of clean-up technologies in an attempt to rehabilitate lands so that they may be returned to economically productive use. Since any given company will have a portfolio of operative and abandoned properties, often on the same site, individual mining firms can use a combination of technologies for environmental management. In some circumstances it has proved possible to combine clean-up operations with the recovery of saleable metals and minerals, although liability provisions in the regulatory framework can militate against this (Tilton, 1994).

28. Regulatory pressure in the United States has produced some innovative approaches to sludge wastes. Under the Resource Conservation and Recovery Act, landfill disposal is not an option for a defined set of hazardous wastes. This encourages the utilization of sludge as a smelter feedstock. Not only does this innovative approach facilitate clean-up at the site and produce a solid waste that can be used as a lime flux replacement in lead smelting operations, but it also enables the recovery of saleable metals (Mosher, 1994).

29. An interesting example, from a developing country, concerns the Chilean firm REFIMET, which, in collaboration with the Centro de Investigación Minera y Metalurgica (CIMM), has developed an innovative process to clean arsenic-rich concentrates (Crozier, 1990). The process is so successful that, in addition to processing Chilean ores, REFIMET imports concentrates from Lepanto in the Philippines and from Greece containing 10 per cent arsenic.

30. Of major concern regarding contamination in water effluents due to inadequate control technology are ammonia, cyanide and thiosalts. In the past, Canadian regulation has shown some degree of flexibility in setting and regulating targets or guidelines for ammonia in effluents. Such flexibility is expected to be phased out and the clear challenge is that improved ammonia control technology is needed. To meet this need, a major new initiative is being made to jointly fund a cooperative programme with industry, to examine the limits of known technologies and investigate new technologies for ammonia control.

31. The treatment of organics in effluents is receiving increasing attention, and considerable success is being achieved using biotechnological methods, particularly in the oil industry. Some modifications to address problems in the

mineral industry can be made. For example, a process has recently been developed where a waste stream containing sodium oxalate from bauxite leaching has been successfully treated to degrade the oxalate to acceptable levels.

32. With the consideration of water as a scarce resource, it can be expected that recycling will be increasingly seen as the best approach for its conservation. These influences will demand that efforts be made to maximize the recycle rate of the water used by any mining or metal-processing facility.

33. The United States-based Cyprus Copper Company has recently been undertaking an environmental impact study for developing a new gold mine near Waitii in New Zealand. A major concern of public groups has been the possibility of cyanide escape due to flooding of the tailings as a result of high rainfall. After testing several methods of destroying cyanide so that the process water could be safely discharged, a new technology was developed: acidification, volatization and reneutralization (AVR). This technology allows the company to remove and recycle cyanide before it goes to the tailings pond. Not only does AVR help to solve environmental problems and thereby facilitate future permitting and mine development, but it also economizes on the use of cyanide (an expensive reagent) and improves the recovery levels of gold and silver.

F. Planning for closure and land remediation

34. While the innovation of individual remediation technologies will facilitate the clean-up of existing and abandoned mines, organizational innovations such as "planning for closure" are keys to improving the long-term environmental management of new mines. The concept of planning for closure is simple: build environmental efficiency into the mine development plan from the outset.

35. At Homestake's McLaughlin Gold Mine in California, several innovative technologies and management techniques are combined to define "best-practice" in environmental management. This mine, opened in 1988, is perhaps the best example of a new mine and processing facility which has been designed, constructed and operated from the outset within the bounds of probably the world's strictest environmental regulations. Environmental efficiency is built into every aspect of the gold mining process in terms of innovative process design criteria, failsafe tailings and waste disposal systems, and extensive ongoing mine rehabilitation and environmental monitoring systems. The mining operation therefore combines innovative technologies with "best practices" in environmental management. The most interesting conclusion drawn from site visits and discussions with the firm's environmental officers is that most of these environmental management initiatives have not resulted in any substantial extra cost and indeed many of these have apparently improved mine efficiency, affecting positively the overall economics of the operation.

36. The decommissioning plan of the Boliden Mineral Company in Sweden is another interesting case in that the company built into its various tailings pond reclamation schemes quite different reclamation measures, all aimed ultimately at reducing the future potential of the tailings to produce acid mine drainage problems. Although similar metals were extracted from each mine, different geochemical characteristics, mine ages, geographical factors and

climate conditions required quite different decommissioning solutions - again suggesting the impracticability of Best Available Technology standards and mining regulations. Boliden was able to implement decommissioning plans which fully utilized the advantageous factors specific to each location (Warhurst, 1994b).

37. Terranalysis, an affiliate of ATW Inc., based in California, has developed a revolutionary method for characterizing and remediating contaminated sites in situ. The unit employing this method, called TerraSURE, is capable of creating isolated, functional process reactors in the subsurface of hazardous waste sites, landfills or tailing deposits where in situ bio-remediation, chemical degradation and solvent extraction can be carried out.

38. In Jamaica, Alcan, foreseeing impending environmental regulation and responding to public concerns locally in Canada, supported university research to develop an innovative solution to the disposal of red mud sludge from its bauxite mining operations. The university developed a process called red-mud stacking which involved sun-drying the sludge to remove much of its moisture content and stacking the material into less obtrusive piles, which in the form of bricks may have further use on the plant site. There is concern, however, that the company may be swapping one pollution problem, solution leakage from slurry reservoirs, for another, dust pollution from drying red mud sludge with a high caustic soda content (Warhurst, 1994b).

39. In 1980, the Superfund Act gave the United States Environmental Protection Agency (EPA) the authority and resources to investigate and clean up releases of hazardous substances. In 1983, a 385 ha parcel of land within a 1.6-km radius of the Ruston/Tacoma smelter was listed as part of the Commencement Bay/Near Shore Tide-flats Superfund site. In 1992, EPA officials recommended a novel approach to remediation. Rather than cleaning up the area without considering its potential reuse, the agency suggested that Asarco involve the community in future land-use planning at the same time that site remediation planning was under way. By merging two very distinct activities into one coherent project, the company could plan, for EPA consideration, a remediation strategy that would be compatible with, and supportive of, eventual land-use after the clean-up. That cooperation, in the end, was the catalyst that enabled Asarco to refine a solution to the Ruston/Tacoma clean-up that will meet the objectives of the company, environmental regulators and the local community (Technology Mining Environment Management, 1995).

II. MANAGEMENT AND APPLICATION OF STATE-OF-THE-ART TECHNOLOGIES

A. Corporate environmental trends

40. The levels of investment in R&D for cleaner, more productive techniques and the commitment to improving environmental performance vary considerably across firms in the industry. Recent research has demonstrated that variation in environmental performance amongst firms is closely correlated to the level of investment in capital equipment and the capacity to innovate (Warhurst, 1993). Research shows how technological innovation has enabled some companies to

respond to regulatory and market pressures by reducing production costs and environmental damage costs simultaneously, thereby improving their competitive position within the industry.

41. However, market pressures - a real decline in metal prices, combined with economic inefficiencies - mean some companies are going bankrupt or are heavily subsidized. They will leave a legacy of environmental pollution, and the burden of clean-up will fall on the State and society. Other companies will respond by innovating: building into the new generation of technology both improved economic and environmental efficiencies

B. Drivers of innovation in clean technology

42. A key issue in improving environmental performance is the identification of the factors which drive mining firms to invest in new production technologies and implement organizational change. Public policy can then be designed to foster these incentives, and remove obstacles to their effectiveness. Although individual firms tend to be responsive to specific pressures and opportunities, evidence suggests that the principal factors are regulatory pressure, public pressure, new market opportunities, and the increasing conditionality of finance.

43. Environmental legislation has burgeoned in the last 20 years in industrialized countries. Most regulatory regimes now have policies for pollution clean-up, emission and effluent standards, best available technology, environmental impact assessment, closure planning and bonding, and public participation. Many developing countries are currently implementing comprehensive environmental policies, often modelled on those operating in industrialized countries. By redefining what are acceptable levels of emission to the environment, new legislation has forced many firms to reconsider the way they do business and to find ways of reducing emissions. Avoiding regulatory hurdles and expediting permit procedures is a further incentive to promote improved environmental management. For some firms, regulation has provided the incentive to invest in new processes which are able to lower overall production costs.

44. To the extent that regulatory pressures reflect the operation of the political process, it is important to not overlook the role of citizen groups in mobilizing popular support for improved environmental protection. The socio-political context of environmental legislation comprises numerous activist groups operating at scales from the local to the global. The activities of these groups have forced environmental issues onto the political agenda, making it hard for corporations and Governments to ignore environmental concerns.

45. A number of specific policies are particularly effective agents of change. Access to information on environmental performance has proved an especially valuable tool in other sectors to encourage firms to respond to public opinion and clean up the production process. The ability of citizen groups and other interested parties to litigate against a State agency for failure to adhere to its responsibility under existing legislation has also proved an effective, if often protracted, means of ensuring the consistency of regulatory pressure.

46. There is a growing market for environmental technologies, services and expertise. Technological development has proved a lucrative new profit centre for some firms. Mt. Isa Mines, to cite one of them, has developed a very successful technology marketing group which has licensed a number of products including ISASMELT, the Jameson Cell and the ISA PROCESS, a copper refining technology. By 1994 the ISA PROCESS had been licensed to 34 operators, and when all licences are in production, this will represent 20 per cent of global production. The development of flash converting by Kennecott and Outokumpu has already sparked interest in possible licensing arrangements. Technology marketing provides an opportunity to recoup R&D costs, although it is unlikely that technology licensing will become a new profit centre for mining.

47. Capitalizing on the need for environmental services and expertise, Anglo-American Corporation has established an Envirolink service, a consultancy service providing skills and resources to develop and implement environmental management systems. This represents an extension into the environmental arena of the traditional service facilities provided by a mining house. A similar role is played by RTZ Consultants.

48. There is some evidence to suggest that mineral markets may be indirectly sensitive to the environmental performance of the producer firm. Although the buyers of mineral products are generally not as sensitive to the environmental conditions of production as are the buyers of consumer products, there is evidence to suggest that mineral markets are very sensitive to the reliability of supply and the quality of the mineral. Together with environmental performance, reliability and quality are a function of the production technology, and the process control and quality management systems. In this respect, focusing on the quality and reliability of supply may promote investment in technologies which result in improved environmental performance.

49. Large capital projects such as mining are heavily dependent for their financing on credit. Credit agencies are increasingly aware that poor environmental performance can delay a project significantly and increase exposure to liabilities. As an element of risk, the environmental performance of a company is an increasingly relevant factor in the investment decision. Not only is a good environmental record important in securing financial backing, but there is evidence to suggest that it is also a factor in gaining access to newly liberalizing production regimes. Demonstration of environmental best-practice is increasingly required by banks and financial institutions, such as the World Bank, the Japanese Overseas Economic Cooperation Fund, and loan guarantee organizations involved in financing third world development.

C. Building environmental management capacity and training

50. Technologies for cleaner production in the mining industry need to include the "soft" technologies of training and skill building, environmental awareness at all levels and management capability, and the capacity to innovate. Work on technology transfer has demonstrated the importance of transferring not only clean technological hardware, but also environmental management expertise and the capacity to effect continuous improvement. The ongoing efficiency and cleanliness of many production processes is as dependent upon the level of

managerial skill and process control as it is on the hardware itself. This is demonstrated clearly in the context of the leaching technologies. Although avoiding the potential for atmospheric emissions associated with smelting, the new wave of hydrometallurgical processes have the potential to generate substantial groundwater and surface-water contamination if not adequately managed. The technological hardware itself does not automatically generate improved environmental performance. Preventing contamination from occurring is heavily dependent on the design, operation and management of the leaching facilities, and the ability of management to anticipate and react to potential contamination events.

D. Environmental management systems (EMS)

51. The International Standards Organization is currently developing an environmental management standard, ISO14000, for use worldwide. This standard is being assessed by the European standards organization, CEN, to determine whether it is compatible with the requirements of the Eco-Management and Audit Scheme. If accepted, it is likely that the European Union (EU) will adopt ISO14000 as the standard for this scheme rather than develop a separate standard of its own. The EMS standard of the United Kingdom of Great Britain and Northern Ireland, BS7750, is the first of its type, and is an example of a compatible national management standard.

52. The purpose of introducing EMS standards is to help businesses develop an effective environmental management system or to assess management procedures already in place. This then establishes a recognized, accredited system which goes beyond "green" public relations, providing a structure to enable companies to keep abreast of new environmental legislation and to respond to queries about environmental performance from employees, shareholders, investors or regulators.

53. An environmental management system seeks to integrate environmental responsibility into everyday management practices through changes in organizational structure, responsibilities, procedures, processes and resources, thereby ensuring a continuing high level of environmental performance. The basis of the EMS approach is the familiar management cycle of establishing a policy, implementing it, assessing and reviewing progress, and then making modifications as required. The system must also ensure that environmental objectives are established and made available to the public. These objectives must comply with the legislative and regulatory requirements applicable to the environmental aspects of its activities, products and services.

54. EMS standards have an in-built requirement that the management system shall produce continual improvement in environmental performance. However, the speed and degree of improvement is under the control of management and not the assessor. This means that assessment of the management system against EMS standards is not a guarantee that environmental performance is at an acceptable level, either in the eyes of the assessor or against a particular standard or regulatory requirement. It is simply an assessment as to whether the requirements specified in the EMS are being complied with.

55. The success of this system depends largely on commitment from all levels within an organization and, in particular, the highest levels of management. It enables an organization to claim environmental credence while it is still in the process of sorting out its problems. However, EMS standards do not actually provide an absolute standard or measure of environmental management quality.

III. CHANGING ENVIRONMENTAL MANAGEMENT PRACTICES

56. Prior to the late 1960s, the environment received little public attention. In most industrialized countries, the response of Governments to "localized" pollution problems was ad hoc and involved the enactment of weak regulatory legislation. Since publication of the report of the World Commission on Environment and Development (the Brundtland Report (A/42/427, annex)) in 1987, the term "sustainable development" has gained increasing importance. It is defined as "development which meets the need of the present generation without compromising the ability of the future generation to meet their own needs". The Brundtland Report underscores the essential linkage between environmental quality and economic activity. It is implicit in the concept that economic policy should encompass environmental conservation and that its aim of achieving more equitable economic growth should refer to intergenerational as well as geographical equity.

57. In recent years, faced with a continuing decline in the quality of the environment, many Governments have adopted stronger environmental policies, enacted fresh legislation and regulations, and reorganized and expanded administrative agencies. Special governmental departments for the environment, which have regulatory and promotional roles, have been set up in developing countries (for example, India). The environmental control instruments used in the natural resource sectors of both industrialized and developing countries can be divided into three groups: command and control regulations, economic incentives and disincentives, and environmental liability.

A. Command and control regulations

58. There has been a proliferation of environmental command and control regulations in countries with developing, industrialized and transitional economies. The aim is to safeguard the quality of land, water and air from degradation due to mining and mineral processing activities. The object of command and control regulations is to set standards and procedures to restrict the amount and types of pollution allowable. The standards are, usually, mandatory and may be backed by sanctions which punish breach of permissible limits.

59. Regulation standards, which vary from country to country, are of three main types: emission standards, which control the actual amount of pollution discharged from a particular source without reference to the environment into which it is discharged; quality standards, which control the quality of the environment into which pollution is emitted; and process and product standards, which do not regulate the actual pollution emitted, but rather control the source of the pollution.

60. Command and control mechanisms include Best Available Technology (BAT) standards, clean water and air acts, funds for clean-up and liability determination; and a range of site specific permitting procedures which tend to be the responsibility of local government within nationally approved regulatory regimes.

61. Critics argue that command and control regulations have not always proved an effective way to control pollution, as they often tend to define both floor and ceiling. Polluters have no incentive to discharge less than the regulations allow, and entrepreneurs have no incentive to devise technology that brings pollution below prescribed levels. When regulations stipulate what technology must be used, Governments may not always know what constitutes best available technology or the industry's best practice standards. Moreover, command and control environmental regulations alone are unlikely to solve environmental problems in developing countries, since there are endemic production inefficiencies. Additional barriers include lack of finances, skilled human resources, information about better environmental management practices and access to technology.

B. Economic incentives

62. More and more countries are turning to economic policies of deregulation, privatization and free-market oriented development. For such approaches, the cornerstone of sustainable development is a system of "open" competitive markets in which prices are made to reflect the costs of environmental as well as other resources.

63. There are generally two classes of economic instruments: price-based and quantity-based. The former include pollution taxes such as emission charges, product charges and deposit-refund schemes. The quantity-based instruments are usually linked with tradeable pollution rights, or marketable permits. One option is for the Government to create a "market" in pollution rights; another is to use fiscal measures designed to offer incentives for environmentally desirable behaviour.

64. The chief appeal of economic incentives as a regulatory device for achieving environmental standards is the large, potential cost-savings that they promise. Economic instruments take advantage of the significant differentials in abatement costs across pollutions, and the development of more effective and less costly abatement techniques. Economic instruments are intended to correct market distortions by promoting economically efficient solutions to environmental problems. Policy makers in the United States have found marketable permits preferable to fees as a mechanism for providing economic incentives for pollution control.

65. Chapter 8 of Agenda 21, in addressing economic and environmental policy integration, calls for: the reduction of subsidies which do not conform to sustainable development objectives; the reformation of economic and fiscal incentives to promote environmental and development objectives; and the establishment of new markets in pollution control and environmentally sound resource management.

66. The argument most often used by environmentalists against economic instruments is that they are licences to pollute. The biggest disadvantage of economic instruments lies in the difficulties in computing environmental costs accurately so as to prevent the concept of "full pricing" from being little more than an educated guess, instead of being a scientifically precise calculation. Today, Governments often opt to use economic incentives together with regulations to implement environmental policies.

C. Environmental liability

67. Environmental regulation based on liability uses a variety of legal means to establish responsibility for unacceptable pollution. If environmental clean-up or prevention is not undertaken, financial redress is sought. Environmental performance bonds are the most common form of proactive liability instrument. If firms do not meet their environmental regulations, the performance bonds can be used for the necessary clean-up. Such a mechanism is law in both Canada and Malaysia.

68. First world environmental standards are becoming increasingly stringent and have moved from regulating obvious pollutants such as sulphur dioxide (SO_2), to controlling, for example, the quality and quantity of industrial wastes, the transboundary shipment of hazardous wastes, acid mine drainage, and heavy metals releases. Also, first world environmental standards are increasingly being adopted in third world countries.

69. Criminalization of environmentally unacceptable behaviour has been a recent trend in the United States and elsewhere. Imprisonment and criminal fines are used as deterrents. Moreover, criminal penalties are used to finance rehabilitation.

70. Several EU directives are relevant to the mining industry. Mineral operators are aware of the requirements imposed on their industry under environmental law emanating from the European Community. Under some of the proposals envisaged by the EU, pressure groups would also be able to take action against mineral operators to ensure that various requirements were observed.

71. The challenge of pollution prevention requires that a mix of policy instruments be used, which include command and control measures, social instruments and economic incentives.

IV. CONCLUSIONS: PROMOTING THE ADOPTION AND DIFFUSION OF STATE-OF-THE-ART ENVIRONMENTAL TECHNOLOGIES

72. This report has described a large number of environmental technologies now available with regard to mining and minerals development. Today, two key considerations guide national policies to promote the development, transfer and diffusion of state-of-the-art technologies regarding mining: (a) striking a balance between economic growth and environmental protection; and (b) a shift of focus from end-of-pipe pollution-abatement technologies to cleaner production processes. This shift, to a preventive rather than reactive approach, needs to

be encouraged everywhere, but especially in countries with developing and transitional economies.

A. Roles for United Nations technical assistance agencies

73. United Nations agencies can foster investment in the development and diffusion of state-of-the-art, environmentally sensitive technologies (EST). Favourable policies for business development are necessary if investments are to be made in the research, development and adaptation of EST. Thus, for example, member countries of the Organisation for Economic Cooperation and Development (OECD) provide funds to offset the costs of the risks associated with the development and demonstration phase of new EST. The World Bank, the United Nations Development Programme (UNDP) and other United Nations system development and technical assistance agencies can support such efforts both through development assistance programmes and support of joint ventures. Moreover, according to a report of the European Union, a new growth theory suggests that technological progress and economic development are a function of accumulated investment in R&D and human capital. Importing technology is not an alternative to indigenous R&D.

74. In the developing countries, institutional development and capacity-building to manage technological change is also an essential role for the United Nations system. Measures will be needed to improve organizational and institutional capacities, to upgrade technical and mechanical skills, and to build up capabilities to understand and assess the performance of technologies in specific national and local contexts.

75. A "technology triangle" is considered to be an effective mechanism for understanding capacity-building. The triangle consists of strategic interrelationships between the institutions of science and technology which generate knowledge and skills, business and industry which commercialize and use new technology and Government which sets regulations for directing technological advances. Strengthening the linkages between these points of the technology triangle and creating incentives for cooperation greatly enhance technology development by consolidating national capabilities and linking public and private initiatives to a nation's intellectual and scientific capabilities.

76. United Nations agencies need to develop mechanisms to enhance North-South and South-South technology cooperation. The United Nations also has an important role to play in the coordination of bilateral and multilateral efforts to support institutional networking at the country level, to ensure the better utilization of expertise available within the country itself.

77. Financial arrangements in conjunction with privatization programmes can help to facilitate technological "leap-frogging". Policies to promote the adoption and diffusion of state-of-the-art EST can be incorporated into the structuring, negotiation and financing of privatization programmes.

78. Consultative mechanisms need to be designed to enhance regional cooperation on environmental problem solving in developing countries facing similar environmental concerns and at a similar level of development. The United

Nations could undertake efforts to enhance the exchange of information on the successful implementation of state-of-the-art technologies through international workshops. The dissemination of well-documented "case-studies" could relate to the various stages involved in improving environmental performance such as for: environmental audits; better management of existing plants; replacement of old technology with available pollution prevention technologies; development and introduction of new, clean processes; and economic analysis of the benefits to be realized through the use of state-of-the-art technologies.

79. In sum, the United Nations system could give priority to the training of advisers; demonstration projects that highlight the economic and environmental benefits of the use of state-of-the-art EST; and capacity-building for technology assessment.

B. Roles for multilateral and bilateral development assistance agencies

80. Development banks are endeavouring to ensure that the projects funded by them are environmentally sustainable. The World Bank, for example, now has a strong environmental programme that requires all investment projects to have a prior Environmental Impact Assessment (EIA). These have resulted in extensive and detailed guidelines for mining in such development agencies as the World Bank, the European Bank for Reconstruction and Development (EBRD), the African and Asian Development Banks, and the International Development Bank (IDB) (The Mining Journal Books, 1992). New loans from these agencies contain a component on environmental management. Specific sums are allocated to co-finance, with Governments, the cleaning-up of existing mining pollution as a prerequisite for new mineral investment. Donor agencies such as the Canadian International Development Agency (CIDA) and the Swedish International Development Authority (SIDA) build in-depth training programmes for human resource development in environmental management into many of their prospective mineral investment projects. "Green conditionalities" are being introduced in loans regarding mandatory EIA and the use of best-practice environmental control technologies in new mineral projects. Most new mining operations must undergo some form of environmental assessment before credit approval.

C. Roles of Government

81. Government environmental regulation policies and fiscal incentives can greatly spur the adoption of state-of-the-art EST. Changes may be necessary in taxation policies to promote environmental innovation. Policies dealing with trade, industry, science and technology need to be coordinated. Government expenditure programmes are needed to support R&D, environmental engineering, the development of clean technologies, and training in environmental management. Incentives can be given to stimulate and reward firms for environmental innovation and technology diffusion. It is clear that to ensure both competitive and environmentally sustainable minerals production, Governments need to adopt public policy which goes beyond incremental and punitive environmental regulation.

82. The policy challenge today, in view of liberalized trade, is to keep market firms sufficiently dynamic and to stimulate them to reduce pollution at the source. Policies are needed to help firms improve environmental protection and comply with environmental regulation. Government policies aimed at human resource development programmes and technology transfer may be essential to promote environmentally sound development efforts in the mining industry. Government policies which assist in promoting environmental efficiency, new investments in EST, new supplier links and new forms of technological collaboration can assist in the diffusion of innovative environmental management practices to developing countries while, at the same time, rewarding the innovator.

D. Roles of the private sector

83. The mining and minerals processing industry is beginning to overcome its aversion to technology innovation. Dynamic companies are innovating to overcome economic as well as environmental constraints. Changed technological and environmental behaviour is evident not only in large Australian, Canadian and United States mining companies, but also in developing country-based firms operating in Brazil, Chile and Ghana. However, State-owned enterprises and small-scale mining groups in developing countries continue to face constraints regarding their capacity to change environmentally damaging practices.

84. Technology transfer and technology partnerships, through joint venture arrangements or strategic alliances, can help to build up technological and managerial capabilities. Such alliances are emerging in all the major mineral producing countries and merit the fullest encouragement and support of the United Nations system. Global mining corporations are playing a major role in supplying significant amounts of managerial and engineering expertise through joint ventures and other collaborative trade arrangements. Technology flows can be structured to match regulatory requirements.

85. Agenda 21 proposes two programmes of relevance which could lead to the greater involvement of industry (Skea, 1993). The first encourages inter-firm cooperation with government support to transfer technologies which generate less waste and increase recycling. The second programme, on "responsible entrepreneurship", encourages self-regulation, environmental R&D, world-wide corporate standards and technology partnerships.

86. Business and industry have made considerable progress in articulating their positions on environmental technology cooperation and partnerships, and their readiness to engage in such activities. An example is the Private-Public Partnerships for Urban Environments which is an initiative of three institutions: UNDP, Sustainable Project Management of the World Business Council for Sustainable Development, and the Massachusetts Institute of Technology (MIT) Technology Development Programme. Collaboration is supported by action at two levels: "horizontal or international collaboration" between the three key sets of actors, and "vertical" linkages between each of these three actors and their respective constituencies within countries throughout the developing world.

87. Such technology partnerships may well be the way of the future where state-of-the-art EST in the field of minerals development will enable a balance between economic goals and environmental concerns.

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INTEGRATION OF THE ISSUE OF THE SUSTAINABLE SUPPLY OF MINERALS INTO THE UNITED NATIONS PROCESSES FOR ADDRESSING AGENDA 21

Towards the sustainable supply of minerals in the context of Agenda 21

Inter-sessional strategy paper of the Committee on Natural Resources

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INTRODUCTION

1. The Committee on Natural Resources has expressed its concern that minerals issues, notably issues of the sustainable supply of mineral resources, have received little explicit attention in Agenda 21. 1/ Minerals issues include issues of the continuing availability of mineral resources, as determined by the global endowment and by restrictions on access to that endowment, as well as issues that affect the demand for mineral resources, such as the environmental impacts of minerals use, the efficiency of minerals use, recycling and substitution, all of which are linked by the concept of sustainable consumption patterns.

2. The spectacular technological and economic development and resulting population growth of the nineteenth and twentieth centuries was made possible by the expansion of the use of all kinds of natural resources, above all petroleum and mineral resources. Such resources are the foundation of the energy, manufacturing, communication and construction industries, 2/ and are also the foundation of modern agricultural industry because of its dependence on mechanization, fertilizers, herbicides and pesticides; the level of their consumption of these resources continues to increase.

3. There is a continuing divergence of opinion concerning the long-term availability of mineral resources, due partly to the time-scales being considered, partly to a real lack of knowledge of resource potential (and of recycling potential), and partly to the difficulty of predicting future demand in the context of technological change and possible future substitution of both materials and energy sources. Accordingly, the current emphasis should be on improving global management strategies for the optimal and most efficient supply and use of available resources with minimum environmental impact.

4. The Brundtland report 3/ recognized the special management problems that are being posed for sustainable development by the depletion of non-living resources; it stated that the rate of depletion should take into account the criticality of a given resource, the availability of technologies for minimizing depletion and the likelihood of substitutes being available. Thus, land should not be degraded beyond reasonable recovery. It is especially important that, for minerals and fossil fuels, the rate of depletion and the emphasis on recycling and economy of use be calibrated to ensure that the resource does not run out before acceptable substitutes are available. Sustainable development requires that the rate of depletion of non-renewable resources foreclose as few future options as possible.

5. In recent decades, the concern that the availability of resources would set limits to national or global economic growth has been largely displaced by the more immediate concern that limits are being set by the environmental impacts of the increasing human population and its increasing consumption of resources. Land degradation, scarcity of water and pollution of air and water are perhaps the most pressing problems, but the issue that has captured the greatest attention from Governments has been that of global warming arising from greenhouse gases, in particular from carbon dioxide emissions. The pressure to move away from fossil fuels towards renewable (and nuclear) energy sources is

due more to the evidence of environmental impacts than to any recognition of the clearly finite limits of petroleum supply or of the desirability of conserving this valuable chemical material feedstock for purposes other than energy. Similar environmental concerns are modifying consumption patterns and moderating demand for a number of metallic mineral commodities.

6. At the United Nations Conference on Environment and Development (UNCED), Agenda 21 was developed to address the pressing problems of today and to prepare the world for the challenges of the next century (para. 1.3). The Commission on Sustainable Development was established to promote the implementation of Agenda 21, and has called for the establishment of indicators of sustainable development to help assess progress.

7. The main work on such indicators relates to the capacity of the global environment to absorb the environmental impacts of human activities: usually based on the so-called pressure, state, response model, they are still relatively undeveloped compared to traditional economic and social indicators. 4/ Moreover, environmental impacts are themselves closely related to the increasing use of mineral, energy and water resources, and there is a complementary need for indicators that take account of non-renewable 5/ resources.

8. Agenda 21 also called for identification of balanced patterns of consumption worldwide that the Earth can support in the long term (para. 10 (e)). The concept of sustainable consumption patterns carries with it the concept of sustainable production patterns, and is usually considered in terms of the environmental impacts that provide the short-term constraint. It is recognized, for example, that the major cause of the deterioration of the global environment is the unsustainable pattern of consumption and production, particularly in industrialized countries (para. 4.3). But it is also necessary that the supply be sustainable for as long as required, which in the longer term may become the critical constraint.

9. Ultimately, the global goal must be to devise models for a relatively steady-state society, in which population size is in broad balance with the availability of resources. 6/ The general nature of the problem is well understood, and it is recognized that continuing efforts must be made to encourage greater efficiency and minimize waste. A paper prepared by the Economic Commission for Europe recognizes that the changes in production and consumption patterns to meet the criteria for sustainable development will require action in all fields of economic and social activity, but also suggests that first of all, a proper definition of sustainable consumption should be laid down in a charter. 7/

10. Clearly, as foreshadowed in the Brundtland report, the definition of sustainable consumption patterns must take into account key minerals issues: the capacity of the environment to absorb the effects of resource use, the sustainability of the supply of essentially non-renewable resources, and the possibilities for modifying production and consumption patterns through greater efficiency of use, new technologies, recycling and substitution.

11. Increasing concerns about the environmental impacts of the exploitation, extraction and use of minerals are also leading to economic or sociopolitical constraints on the capacity to meet demand, which is also being reduced more generally by competing land uses as the global population increases. The competition for land use is likely to close additional areas to exploration and development, as it has already done in parts of Europe and the United States of America.

12. It is therefore especially important that issues of mineral supply be considered as part of the approach proposed in Agenda 21, chapter 10 (Integrated approach to the planning and management of land resources). It is recognized in general terms that integration should take place on two levels, considering, on the one hand, all environmental, social and economic factors (including, for example, impacts of the various economic and social sectors on the environment and natural resources) and on the other, all environmental and resource components together (i.e., air, water, biota, land, geological and natural resources) (para. 10.3).

13. However, there is a general tendency to exclude mineral resources from discussion of both land and natural resources, and minerals issues receive little specific attention in Agenda 21, or in follow-up activities (see E/CN.17/1995/2). Notably, there is no chapter in Agenda 21 dealing with the minerals sector, as there is for other sectors, such as agriculture (chap. 14); the present paper attempts to redress that imbalance. It is based on the belief that understanding of the key minerals issues can provide greater coherence to the implementation of Agenda 21, and that such issues have particular importance for developing countries and economies in transition.

Scope of this paper

14. In the context outlined above, the present strategy paper has limited objectives. It aims first to emphasize the key importance of mineral resources for sustainable development and quality of life and, as a consequence, to identify simple low-cost actions at the international level. These will provide new information links to improve the basis for global planning and management strategies, integrating environmental and development concerns.

15. In addition to the goal of an environmentally stable future that is embodied in the Rio Declaration on Environment and Development, 8/ most explicitly in its Principle 7, the United Nations has the parallel goal of improving the living standards in less developed countries (Principles 5 and 6). The United Nations has long attempted to assist developing countries in the development of their mineral resources as a means to implement those principles. It is proposed to discuss the special problems of minerals-producing countries, particularly less developed countries, in a subsequent strategy paper of the Commission on Sustainable Development. However, the international actions proposed in the present paper should also be of particular value to such countries.

16. The present paper discusses both metallic and industrial minerals but not the fuel minerals. 9/ For reasons indicated in the text, the recommendations have particular relevance to the metallic minerals.

17. The main minerals issues identified above require consideration of the whole mineral cycle, from mineral exploration and discovery through extraction, processing, manufacture and utilization to eventual recovery or disposal. Some downstream aspects of that cycle related to waste disposal and pollution are addressed in Agenda 21, chapters 19 (Environmentally sound management of toxic wastes) and 20 (Environmentally sound management of hazardous wastes), and there are many existing projects in this field. 10/ The present paper therefore focuses on aspects of the cycle that bear more directly on the sustainable supply of mineral resources and sustainable consumption patterns, such as efficiency of extraction and use, recycling, new technologies and substitution, all of which are driven at least in part by concern over environmental impacts, and all of which lead to reduction in the rate of increase of the overall demand.

18. The management of mineral resources requires cooperation between private industry and Governments (and other stakeholders) at various levels. In recent decades, exploration for metallic mineral resources has been increasingly dominated by international mining companies with the resources and expertise to find and develop world-class deposits (thus following the earlier trend in the petroleum industry). As a result, the development of such mineral resources is very largely a matter for private industry under the overall control of national Governments and local governments in accordance with Principle 2 of the Rio Declaration on Environment and Development.

19. The recommendations in the present paper are developed in full cognizance of the role played by the international mining industry in the efficient exploration for and development of global mineral resources. They are therefore designed to complement that role within the overall global partnership for sustainable development. Indeed, the actions proposed here will also be of value to the international mining industry in providing an improved knowledge base for exploration and development strategies. They are also complementary to the approach taken by the International Conference on Development, Environment and Mining. 11/ That Conference gave particular attention to public and private sector roles in relation to mining and its environmental impacts, with emphasis on the role of national Governments.

20. The key minerals issues are being addressed with increasing effectiveness at the national and regional levels. But they are ultimately global issues, and their analysis also needs to be undertaken on a global scale. Such analysis, through a global partnership, will also allow a more realistic assessment of the management strategies that are required at the national and regional levels. It is therefore suggested here that the United Nations has a critical role to play in coordinating and integrating information on key minerals issues on a global scale, in accordance with the principles set out in Agenda 21, especially chapter 35 (Science for sustainable development), chapter 37 (National mechanisms and international cooperation for capacity-building in developing countries), and chapter 40 (Information for decision-making).

21. It is recognized in chapter 8 of Agenda 21 (Integrating environment and development in decision-making) that a first step towards the integration of sustainability into economic management is the establishment of better measurement of the crucial role of the environment as a source of natural

capital and as a sink for by-products generated during the production of man-made capital and other human activities (para. 8.41). This natural capital must include the endowment of minerals of all kinds, and one aim of the present paper is to assist in that first step by identifying means for the better measurement of such parameters with respect to minerals.

22. At present, there are important gaps in the global knowledge base; the present paper therefore attempts to define some of the gaps and suggest possible approaches to filling them. It is also suggested that such knowledge gaps can be filled at relatively very low cost by building on existing efforts of many institutions at the national and regional levels.

23. The key minerals issues are also linked by the overriding issue of global population growth. Accordingly, some aspects of the relationship between population, resource use and the environment are discussed below prior to further discussion of the factors that mitigate the effects of resource use or affect the availability of resources.

I. POPULATION GROWTH AND INCREASING DEMAND

24. Global population will almost certainly reach 8 billion over the next 30 to 40 years, and is unlikely to stabilize much below 12 billion before the end of the twenty-first century. 12/ At the same time, efforts must be made to improve living standards in less developed countries. In the absence of major steps towards dematerialization, the demand for materials and energy will continue to increase due to both rapidly increasing population levels and aspirations for improved living standards. There will also be enormous additional burdens on the natural environment due to increasing consumption.

25. The Brundtland report considered that global economic expansion by a factor of 5 to 10 would be required in order to meet the demand for improved living standards for an increasing population. It was apparently believed that such growth could be achieved largely by a more efficient use of materials and energy, as well as by improved technology to reduce environmental impacts.

26. However, there has since been an attempt to distinguish between economic growth, which involves increased inputs of energy and materials, and economic development, which can take place through increased efficiency without increased consumption of material capital. 13/ From that standpoint, it has been suggested that the Brundtland report is too optimistic: an increase by a factor of 5 to 10 cannot come from development alone, and if it comes mainly from growth it will be devastatingly unsustainable. 12/

27. There has been significant decoupling of economic expansion from metallic minerals consumption in developed countries in recent decades. The intensity of use of aluminium, for example (measured in kilograms (kgs) per millions of dollars of gross national product (GNP)), has declined since 1975. 14/ Substitution by non-metallic materials, combined with efficiencies in the use of the metals, partly accounts for the lower intensity of use of metals in industrialized countries. Another contributing factor is the great increase in value-adding in finished products. But although the relative importance of

metals has declined in industrial economies, there has not been significant decline in the absolute quantities of metals used, i.e., there has not been an overall dematerialization. 15/

28. Globally, consumption continues to increase; although demand for some minerals has stabilized, and is even declining in some developed countries, this will be more than offset by increasing demand in developing countries and areas, particularly in South-East Asia, where population is also growing rapidly. For example, per capita consumption in the newly industrializing Republic of Korea and Taiwan Province of China has grown rapidly over the last 30 years to levels similar to those of the industrialized countries. Recent analyses 16/ also show that between 1950 and 1990, the population in underdeveloped regions grew from 68 to 77 per cent of the global population, while the share of consumption of various metals grew from between 1 and 5 per cent to between 12 and 25 per cent.

29. For similar reasons, it seems likely that the demand for fuel minerals will continue to increase for several decades. 17/ However, the demand for energy has continued to increase in the developed as well as the developing countries. Such increased materials and energy use will inevitably be accompanied by increased environmental impacts.

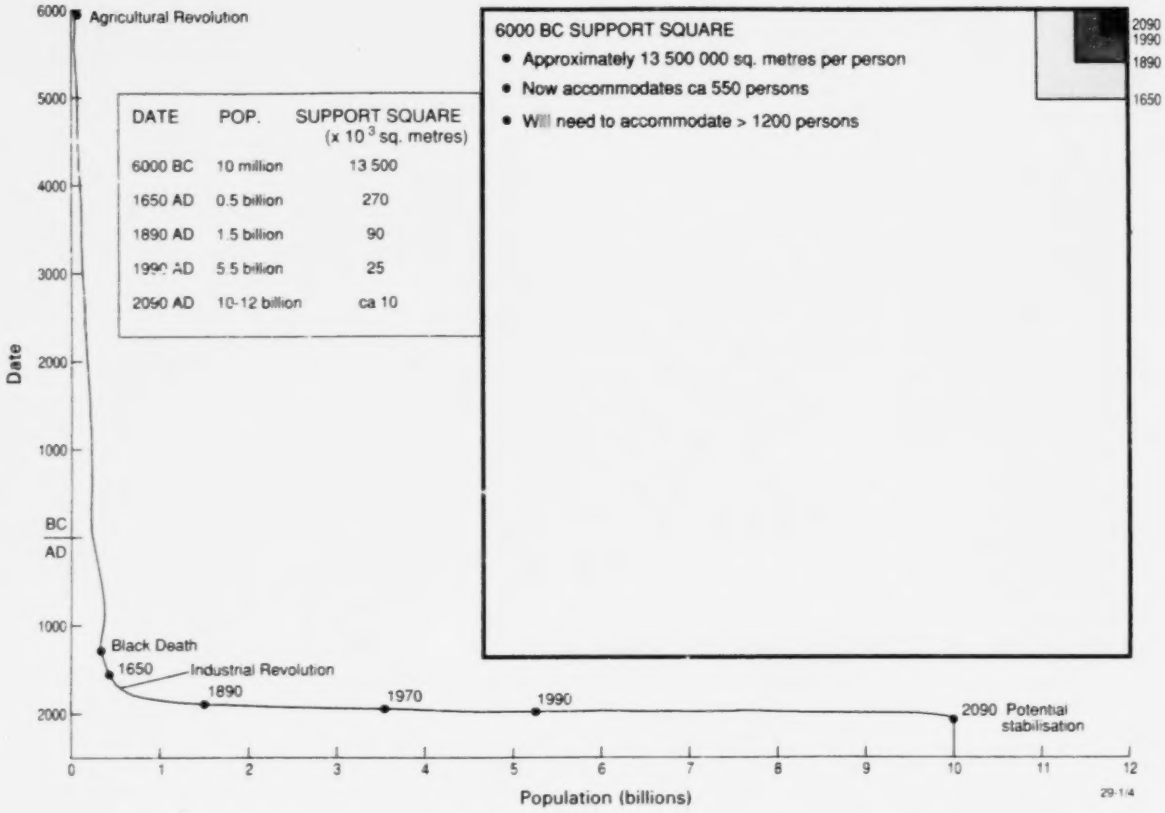
30. Population, resource use and the environment can also be clearly linked through the concepts of per capita use of resources and per capita use of space. The total impact of the human population is the product of population and per capita resource use, 18/ and it can be controlled by controlling either or both.

A. The support square

31. The per capita use of space is defined by the total available area divided by the total population and has been called the support square, which has been described as the scrap of land that must supply all the resources that an individual uses throughout a life, and that must fulfil the same purpose for others who follow. Somehow, that space must also consume most of the solid wastes left over. 19/ This anthropogenic concept actually overstates the area available per capita, since the need to preserve areas of natural environment and biodiversity must also be recognized: the same total area must support most other land-based species as well as the human population.

32. Nevertheless, the diminishing size of the support square gives a very graphic illustration of the impact of the increasing human population (see figure 1). The average global support square towards the end of the next century is likely to be about 100 metres square, about the same as the local support square for Europe today. But Europe offers a particularly favourable environment for human habitation. Moreover, like other developed countries in North America and Asia, European countries are not wholly dependent on the local support square: they obtain a substantial part of their resources from other less densely populated regions.

Figure 1. Growth in global population and resulting shrinkage in the global support square



33. To a considerable extent, therefore, environmental impacts associated with the production of both renewable and non-renewable resources are also borne elsewhere. As the global population increases with its attendant environmental impacts, pressures on land use will also increase, as will pressures on the natural environment and on biodiversity. The expanding densely populated regions will place increasing pressure on the shrinking less densely populated regions to supply resources, and it will become increasingly difficult to guarantee external supplies of both renewable and non-renewable resources. It will be increasingly necessary to recognize mineral supply as a global issue that requires global management strategies (see sect. III below).

B. Per capita resource use

34. The average per capita consumption of all minerals has been estimated at close to 10 tons per annum. The total impact for the global population involves the displacement of about 50 billion tons of minerals per annum, a figure substantially greater than the amount of material moved by natural processes. A large proportion of this material consists of industrial minerals, which are relocated from quarries to the sites of growing cities and to transport networks.

35. In the major industrial countries, consumption is much higher than the global average. In Germany, for example, it has been estimated that the average individual, in a lifetime of 70 years, consumes about 772 tons of construction materials, nearly 54 tons of other industrial minerals, about 363 tons of fuel minerals and about 43 tons of metals, mainly steel. 20/ Allowing for the quantities of ore and overburden that are involved in producing the final products, it is likely that some 1,600 tons of rock are consumed by each individual, or well over 20 tons per annum. A wider analysis of material flows in Germany arrived at a figure of 33 tons per capita per annum, excluding water and air consumption, or 1 kg per deutsche mark of gross domestic product (GDP). 21/

36. The volume of rock involved over the average lifetime is more than 500 cubic metres, which corresponds to an area more than 7 metres square excavated to a depth of 10 metres, approximately 0.5 per cent of the 100 metre support square.

37. If consumption on that scale were extended to a population of 10 to 12 billion, the total impact would be more than quadrupled to over 200 billion tons, or approaching 100 cubic kilometres of rock each year. It is hardly possible to argue that such consumption rates are sustainable, either in terms of their environmental impact or in terms of the availability of resources.

38. This discussion serves to illustrate the unsustainability of present demand trends and the consumption patterns that cause them. Clearly, every effort must be made to decouple economic expansion as far as possible from increased use of materials and energy. Targets for sustainable consumption patterns will need to be set in the light of the best possible knowledge of the impact of resource use (see sect. II below) and of the availability of resources (see sect. IV below).

II. TOWARDS SUSTAINABLE CONSUMPTION PATTERNS: MITIGATION OF THE IMPACTS OF RESOURCE USE

39. As noted above, the factors that moderate demand for minerals from primary sources, notably increased efficiency of extraction and use, recycling and substitution, are driven at least in part by concern over environmental impacts, although normal market forces also operate. Those factors are therefore considered below in terms of the directions of change in consumption patterns that environmental impacts may dictate.

A. Environmental impacts of minerals use and response strategies

40. The current relationships among atmosphere, hydrosphere, lithosphere and biosphere are the result of evolution throughout Earth history. The interactions are complex, but rates of change resulting from natural above-ground or exogenic processes are relatively slow on human time-scales, and the natural environment is in a state of dynamic quasi-equilibrium. Soils, in particular, form part of an oxidized zone resulting from interaction between bedrock, air, water, plants and animals.

41. The environmental impacts of minerals extraction and use arise from the disturbance of the natural balance of earth processes. In the case of phosphate, for example, phosphate that has been sequestered by natural exogenic processes over hundreds of millions of years is being returned to the land surface on a time-scale of a few hundreds of years.

42. Metallic ore deposits, in contrast, are largely formed by subsurface or endogenic processes, and are unusual concentrations of elements that normally have very low concentrations in soils and water. The ores are largely derived from below the oxidized zone, which is broadly in equilibrium with air and groundwater. Both natural weathering and mineral processing therefore involve the oxidation of mineral ores and the release of various pollutants, including sulphur dioxide and toxic trace elements.

1. Metallic minerals

43. One of the major impacts of the use of metallic minerals arises from the energy used in their production: the timing and nature of any changes made in the energy mix will have major implications for the mineral industry as a whole. Gases released in the production process, notably sulphur dioxide, also cause environmental problems, such as acid rain, and are important in climate change analyses. A number of the metals also have an intrinsic toxicity, so that they can cause unacceptable pollution (as with lead in petrol).

44. The International Council on Metals and the Environment (ICME) has been established by the international mining industry to promote sound environmental and health policies and practices in the production, use, recycling and disposal of non-ferrous and precious metals. It has cooperated with the organizations and bodies of the United Nations system, including the United Nations Conference on Trade and Development (UNCTAD), the United Nations Environment Programme (UNEP) and the Department for Development Support and Management Services of the United Nations Secretariat, as well as with other international bodies, such as the Organisation for Economic Cooperation and Development (OECD). More generally, the environment has become a core business issue, as ecological and economic factors are merged into the practice of business management, 22/ and much technological progress is being driven by market forces.

2. Efficiency of minerals use and impact mitigation

45. The ideal industrial ecosystem would have a minimal input of primary materials, including metals. Inputs can be reduced by more efficient processing throughout the cycle, by reduction of waste and by recycling. For example, in 1994, reclaimed metals and mineral materials in the United States of America accounted for about one quarter of the total mineral raw materials used. 23/ For specific metals, such as lead and copper, recycled material may account for well over half the total consumption in industrialized countries. Recycling trends are being monitored by various national organizations and ICME has commissioned a study on the recycling of non-ferrous metals and its benefits, issues and trends.

46. Environmental impacts can be further reduced by improved treatment of waste, and where necessary and possible, by substitution. For example, there may be an opportunity to use waste materials from the production of high-value commodities to substitute for primary raw materials in the production of low-value commodities, as in the use of fly ash derived from the production of electricity based on coal as a substitute for primary raw materials for cement production.

47. There has been increasing substitution for metals by new materials and composites. 24/ Some of these, such as ceramic materials, inorganic glasses and optical fibre, are derived from relatively common rock-forming minerals, while others, notably plastics, depend on the supply of the fuel minerals; relatively few are derived from renewable materials. In general, therefore, substitution involves replacing one non-renewable resource by another. It does not contribute substantially to dematerialization, although it may contribute substantially to the reduction of environmental impacts.

48. One reason for substitution of metals for some purposes is that less energy is required for their production (for example, for the production of paper and plastic products) than is required for equivalent metallic products. However, the differences are not so large as to overcome other factors, such as specific properties and processability for particular purposes. There have also been great improvements in the energy efficiency of primary production and forming of metals, and further improvements are possible.

49. Some attempts have been made to assess the environmental impact of extraction and processing involved in the primary production of metals. For example, a pilot study of mass balances (inputs and outputs) in the production of nickel has been undertaken in Germany. 25/ The study took into account the different flows involved in the processing of laterite ores of various types and sulphide ores. The quantitative information obtained from such studies could be used in assessing the total environmental impacts of alternative source materials.

50. Attempts are also being made to assess the environmental impacts of the production of various goods by focusing on material inputs and taking into account all phases of product life-cycles, notably at the Wuppertal Institute. It is postulated that the totality of all life-cycle material movements, including the materials consumed for the provision of transportation and energy,

serves as a proxy for the environmental impact potential of goods. 26/ It is therefore proposed to classify products according to material input per service unit. The main aim is to assist in overall dematerialization strategy by developing eco-efficient service concepts, through which service unit output is increased while material input remains constant or is decreased. Clearly, general reductions in material inputs, including energy materials, would also lead to general reductions in waste and in any toxic chemical flows.

51. It seems likely, however, that the main approach to environmental impacts related to metallic minerals will continue to be through addressing the problems of particular identified adverse outputs from the industrial ecosystem. Agenda 21, for example, deals specifically with the environmentally sound management of toxic chemicals in chapter 19, of hazardous wastes in chapter 20, and of solid wastes and sewage-related issues in chapter 21. Nevertheless, such strategies will be more effective if it is recognized that those outputs are specifically related to material inputs that may themselves be subject to modification. In considering alternative material inputs, knowledge of any eco-toxicity of products throughout the life-cycles of the alternatives must be considered, and there is a need to promote careful management to minimize potential impacts. Remedial measures may therefore be possible at all stages in the product life-cycle.

52. ICME has paid particular attention to the methodology of risk assessment. Work has been undertaken to describe metals and their toxicities, and to provide an overview of current methodologies and related biases.

53. The need for baseline studies against which to assess environmental impacts is discussed in section II.B below.

3. Industrial minerals

54. In the context of land-use planning, it is clearly important to take particular note of the demand for industrial minerals, which as noted above form the dominant component of total material usage. Debate about the depletion of mineral resources has been mainly concerned with the metallic and fuel minerals, with the implicit assumption that supplies of industrial minerals are inexhaustible. However, because of the enormous quantities involved and because they are not readily recycled, the supply of industrial minerals raises particular problems of environmental impacts.

55. It might be supposed that once the main infrastructure of industrialized countries has been established, the need for construction materials (for replacement and maintenance) would be significantly reduced, thus contributing to the process of dematerialization. 27/ Apparently, however, this stage has not yet been reached in Europe. Although population there has stabilized, the annual consumption of construction materials continues to increase, and there is widespread concern about the environmental impacts of quarrying and transport. 28/ To meet the demand, there has also been an increase in the amount of sand and gravel derived from shallow offshore areas, and coastal superquarries have also been developed. Indeed, it has been suggested that sustainable development of the coastal zone may require imposition of a littoral

or thalassic tax that, like a carbon tax, takes a global view of the "polluter pays" principle. 29/

56. Thus, the rate of consumption of construction materials and the environmental impacts of such consumption are clearly important issues for the promotion of sustainable construction industry activities (see Agenda 21, chap. 7G).

57. Among industrial minerals, phosphate has a special importance because of its essential contribution to the productivity of the agricultural industry. 30/ Phosphate production increased roughly sixfold between 1950 and 1980 to about 150 million tons per annum (roughly 30 kg per capita globally and almost 50 kg per capita in some countries). Phosphate production has fallen recently because of the near collapse of output from the former USSR but is likely to continue to rise in the future to meet the needs of the growing global population. Reserves are very large 31/ but are clearly finite and unevenly distributed. As is the case for petroleum, however, the principal concern is the environmental impacts of phosphate use that result from the greatly increased levels of phosphate, especially in inland waters. But there is no substitute, and it is difficult to control and reduce consumption.

4. Technical assessment of impact mitigation and changing demand

58. Under the heading of "International cooperation and coordination", Agenda 21 suggested that reviewing the role and impact of unsustainable production and consumption patterns and lifestyles and their relation to sustainable development should be given high priority (paras. 4.12 and 4.13).

59. At its third session, the Commission on Sustainable Development noted the initiative taken by the Government of Norway in hosting the Oslo Round-table Conference on Sustainable Production and Consumption (6-10 February 1995) and its contribution to underlining the importance of focusing on demand-side issues as a complement to the traditional supply-side approach.

60. The Commission also called for intensified efforts to reduce the energy and material intensities of production and consumption through improving energy efficiency, taking energy-saving measures, technological innovations and transfer, increased waste recovery, and reusing and recycling of materials, and it noted the value of the life-cycle approach in assessing environmental impacts.

B. Monitoring the mineral cycle

61. In so far as they fall within its mandate, UNCTAD has addressed aspects of the issues discussed above and noted by the Commission. For example, it has considered standards and regulations relating to process and production methods, and it has also considered environmentally friendly products and eco-labelling in the context of international trade (see E/1994/47). Some relevant work has also been undertaken by the United Nations Industrial Development Organization (UNIDO) and UNEP.

62. However, there appears to be no standing United Nations body that is concerned with the technical aspects of materials and energy use in the industrial ecosystem. Much work in this area is currently being carried out in the industrial countries, 32/ but there appears to be no provision for systematic and continuing analysis of such research at the global level that could provide ongoing assessments of the technological progress being made towards sustainable resource use, i.e., of the potential of improved efficiency, recycling, new materials technology and substitution for reducing material and energy inputs and minimizing undesirable outputs (wastes).

63. Such analysis would be valuable in encouraging world best practice in the mitigation of environmental impacts, both in industrialized and developing countries, and would also be of great value in assessing future demand for primary material and energy inputs to the industrial ecosystem.

64. The work could be carried out by an appropriately constituted United Nations technical commission. The Commission for Hydrology of the World Meteorological Organization (WMO) provides a general model of such a commission, although there is no parent body in the minerals area corresponding to WMO. The expertise for a commission for materials would be drawn essentially from the engineering and materials science disciplines, and would provide a high-level body in the United Nations for input from the technological sciences and engineering.

65. In addition, the scope of such a commission could be broadened to cover the issues relating to availability of resources (which are considered in sect. III below), as well as expertise in the areas of geology resource assessment and mining engineering, and would provide an appropriate technical link to bodies concerned with the mining sector, including ICME.

Recommendation 1

66. It is therefore recommended that a commission on mining and materials be established to assess and report on technological progress towards the sustainable use of resources through improved efficiency, new technologies, substitution and recycling.

67. The mandate of the proposed commission should include the compilation of information on the total impacts of the use of various commodities as an essential basis for determining optimum consumption patterns. This would involve an assessment of mass balances in the use of commodities, as well as the assessment of material inputs per unit of service, and would also provide input to the assessment of future demand.

68. In addition, such a commission could assist the United Nations in identifying opportunities (e.g., in extractive metallurgy technology) in its capacity-building programmes for technology transfer to non-OECD countries.

69. The mandate should also include the study of the technology of resource discovery and extraction, trends in the efficiency and cost of new mineral resources, and trends in recycling.

C. Monitoring the terrestrial environment

70. Because natural processes and human activities are continuously modifying the chemical composition of the environment, it is necessary to monitor the health of the surface of the solid earth in the same way as the health of the oceans and atmosphere are being monitored. The natural concentration of chemical elements reflects the variability of the geology, and knowledge of the natural variation can be critical in assessing pollution at all scales resulting from any stage of the mineral cycle.

71. The final report of the International Geochemical Mapping Project of the International Geological Correlation Program 33/ has addressed the need for a coherent, systematic, worldwide, multi-element geochemical database, and has made a comprehensive analysis of the basic requirements and likely costs.

72. The report points out that such a database is pertinent to the administrative and legal issues that are involved in the sustainable long-term management of environmental and mineral resources, and contains information that is directly relevant to economic and environmental decisions involving mineral exploration, extraction and processing; manufacturing industries; agriculture; forestry; many aspects of human and animal health; waste disposal; and land-use planning. It has been established that available data are substantially incomplete and internally inconsistent. Evidently, the data required could be obtained by enlisting the cooperation of national geological surveys. The necessary central coordination could be carried out by an appropriate United Nations agency. Such a global geochemical database would complement and enhance the value of other data sets, such as the Land Data project using Advanced Very High Resolution Radiometer (AVHRR) data.

Recommendation 2

73. It is therefore recommended that a programme to produce a global geochemical database be implemented, as identified and evaluated by the International Geochemical Mapping Project of the International Geological Correlation Program, in order to provide an essential contribution to objective and effective environmental and resource management.

74. It has been estimated that full data acquisition will require a minimum of a decade. Given the immediate relevance of such data to intensifying land-use problems, the programme should be initiated without delay. Central coordination will be necessary for the duration of the programme, and progress should be expedited and facilitated by a small technical secretariat, funded and administered through a recognized international organization. Individual countries should be encouraged to support and participate in the work.

III. TOWARDS SUSTAINABLE CONSUMPTION PATTERNS: AVAILABILITY OF RESOURCES

A. General outlook

75. The supply of mineral resources is essentially a response to demand that has largely been regulated by the price mechanism. Because of the success of the mineral industry in meeting demand in recent decades, there has been plentiful and low-cost supply, stimulating consumption and therefore demand. That situation was temporarily changed by the oil price shocks of the 1970s. In general, as discussed in sections I and II above, levels of demand do change through time, not only as a result of changes in cost but also because of substitution, recycling, technological advances or environmental concerns. It is necessary to consider, however, whether the resulting production and consumption patterns are also sustainable in terms of availability of resources.

76. Current knowledge of the future availability of resources (and therefore of whether production and consumption patterns are sustainable) is based essentially on the assessments of identified resources, which are not readily related to prospective mineral provinces or to longer term mineral potential. It is clear from these assessments, however (see sect. III.B below), that the supply of mineral and petroleum resources over time-scales of a few decades is well assured. The trend towards the internationalization of major resource companies, allied with increasingly effective exploration methodologies, has permitted the ready maintenance of the world's stock of economic identified resources. Technological advances in mining methods and mineral processing (e.g., for gold and copper) and strong competition have also resulted in stable or declining deflated commodity prices. 34/

77. Available information on identified resources, however, does not provide an assurance of supply over the longer time-scales of sustainable development as far as the potential stabilization of the global population at the end of the next century or the potential development of a steady-state further in the future.

78. The evident continuing success in meeting demand, however, must be set against the relatively short period that has elapsed since the industrial revolution, when such resources first began to be exploited on a large scale, as well as the current exponential growth in demand. Mineral resources are essentially non-renewable, and the economic resource potential has been severely depleted during the twentieth century at an ever increasing rate. There is no doubt that there are real limits to the availability of ore deposits of the kinds and grades currently being mined: the trend towards utilization of lower-grade ores is already well-established.

79. The issues involved in assessing the sustainability of mineral supply in the long term have been comprehensively addressed in the scientific literature but have received little explicit attention in Agenda 21 or the more general debate on sustainability. There has been a tendency to take either too pessimistic a view, using published figures of ore reserves, or too optimistic a view, on the basis that mineral resources are essentially infinite and that

economically benign solutions will be found to the technological problems when scarcities of conventional mineral deposits emerge.

80. In the very long term, it is hardly possible to predict how far technological advances or specific scarcities will lead to reduced demand (dematerialization) or successful substitution (especially of energy), by renewable resources. Eventually, the development of non-polluting energy sources may largely solve the problems of resource supply by allowing the extraction of minerals from sources that cannot at present be exploited economically without unacceptable environmental impacts, but the time-scale of any such development is very uncertain.

81. Meanwhile, usage continues at rates that are not sustainable in the long term. During the period of increasing global population and increasing demand for mineral resources, it is prudent to be well informed of constraints on the future availability of mineral resources. Current knowledge of the global potential for discovering new deposits is very limited, and this deficiency must be addressed. There are also increasing pressures on land use, which may make it increasingly difficult to explore for and develop available resources. The above-mentioned issues are discussed below. It is not a question of running out of resources but of avoiding potential problems and ensuring the optimum and efficient use of available resources with minimum environmental impact.

B. The horizon of sustainability: identified and undiscovered resources

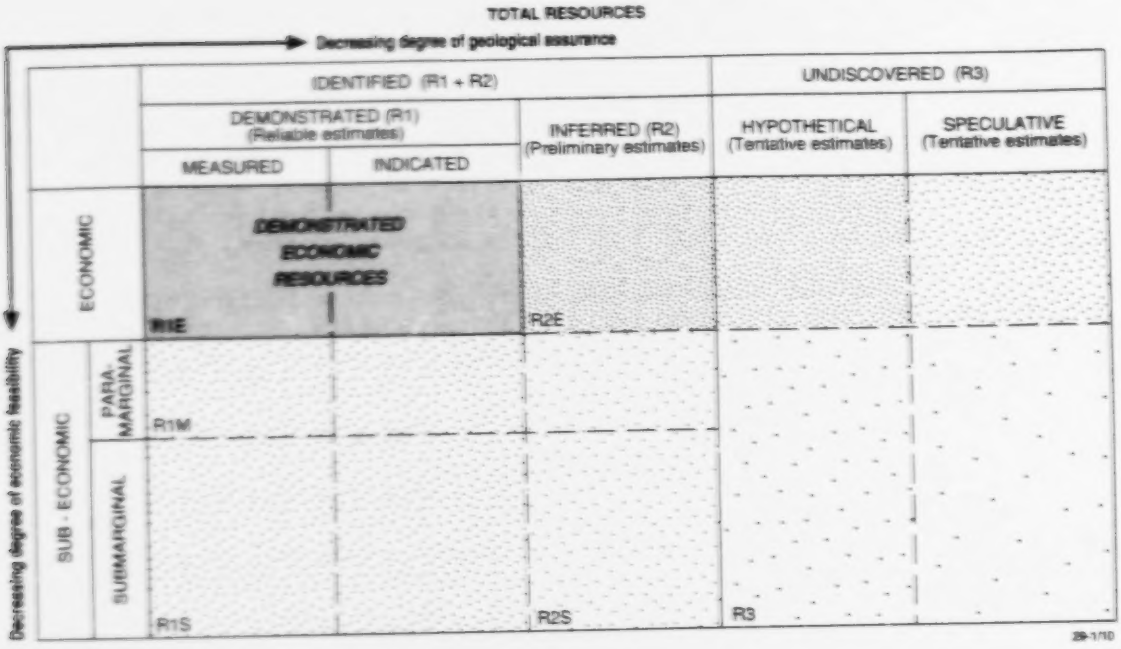
1. Identified resources

82. Most existing national and international assessment programmes are limited to the assessment of identified resources, especially demonstrated economic resources (DER), i.e., that part of total resources that has been identified by exploration and drilling and can be extracted economically under current conditions (see figure 2).

83. The stock of DER can be related to the changing demand for (and therefore production of) a particular commodity by the resource-production (R/P) ratio. Time series of production, DER and R/P ratio illustrate the availability of mineral resources through time, and indicate the effects of past changes in demand, including their major social and economic impacts. They also demonstrate that the stock of DER is not a fixed stock that is continually being depleted. On the contrary, it is continually being renewed either by discovery of new economic resources or by transfer from the large pool of known but previously sub-economic resources, as a result of technological advances or price rises induced by scarcity.

84. In general, the annual production of mineral commodities has increased greatly and steadily this century, but DER have also increased, so that R/P ratios have been maintained. In the case of bauxite, however, DER has been maintained but the R/P ratio has declined because of greatly increased annual production.

Figure 2. Australian resource classification system a/



Key

R - in situ resources

R1 - known deposits (reliable estimates)

R2 - extensions of known and newly discovered deposits (preliminary estimates)

R3 - undiscovered deposits (tentative estimates)

R1E - economically exploitable

R2E - economically exploitable

R1M - marginally economic

R2S - sub-economic

R1S - sub-economic

Source: Australian Bureau of Mineral Resources (1984); see "BMR refines its mineral resources classification system", Australian Mineral Industries Quarterly, vol. 36, No. 3 (1984).

Note: Sub-economic categories also represent unusual concentrations of the relevant elements, and can be reasonably well defined for particular deposit types.

a/ Modified McKelvey system, also showing United Nations resource categories.

85. The large tonnage commodities, such as coal, iron ore, bauxite and phosphate, have large R/P ratios (in the hundreds of years). However, such minerals occur in near-surface deposits: the capacity to continue to renew the stock of their DER is in some doubt. Moreover, such mining also has the largest immediate (if transitory) environmental impact.

86. For most of the metallic minerals, R/P ratios are much smaller (in the tens of years), but again it has been possible to maintain their ratios, reflecting the capacity of the minerals industry to take a relatively long-term view of future demand and of the factors likely to affect it, and to make appropriate investment in exploration and development. The time-lag between such investment and the establishment of new DER is typically 10 years or more. 35/

87. Resource/production ratios therefore provide a clear horizon of the sustainability of supply, usually of about 30 or 40 years. In terms of the supply constraint, this also provides a horizon of sustainability for production and consumption patterns.

2. Undiscovered resources

88. In contrast to the situation for petroleum, there are no reliable global estimates for the undiscovered resources of metallic minerals. There are many different types of deposit, the processes that generate them are very complex and less well-known than those that generate petroleum deposits, and methodologies for estimating undiscovered resources are much less reliable. Most of the methods that have been employed are of a very general character, and do not permit information about undiscovered resources to be linked in integrated systems of land use and management.

89. This is unfortunate, since it tends to foster the notion that metallic mineral resources are unlimited, since the total amount of most metals and other mineral commodities in the earth's crust is very high. In most rocks, however, metallic elements occur in very low concentrations and not in discrete minerals, so that their extraction is not feasible. Metallic mineral deposits, whether currently economic or sub-economic, result from particular conjunctions of processes in the earth's crust that have led to the deposition of unusual concentrations of metals as mineral ores in particular locations.

90. It is possible that mineral deposits of the kinds currently regarded as economic or sub-economic will be quite limited by comparison with the resources already identified. Their distribution is highly heterogeneous at various scales, both in area and in depth. Different kinds of deposit are characteristic of different geological environments, so that their occurrence is limited to particular mineral provinces. Moreover, many deposit types are formed close to the earth's surface, so that the opportunities for discoveries below the uppermost few kilometres are likely to be relatively limited.

91. Many of the more prospective terrains of the world have already been extensively explored by modern methods, so that the more readily detected deposits have already been discovered. Exploration techniques, however, are continually being improved in the search for concealed deposits. Other terrains

have only recently been opened to the international exploration industry, and there will undoubtedly be major discoveries over the next few decades. It is likely, therefore, that the horizon of sustainability can be pushed back into the second half of the twenty-first century. Nevertheless, based on the current state of knowledge, it is prudent to recognize that there may be real problems in meeting demand over the next century, which may be increased by political factors and more generally by restrictions on the availability of land for exploration, as discussed below.

C. Strategic factors

92. The uneven distribution of mineral deposits world wide means that the sources of supply of some commodities, such as platinum, chromium, vanadium and manganese, are highly restricted geographically. In recent decades, for example, South Africa and the former USSR have accounted for over 80 per cent of world mine production of platinum group metals. Such commodities will continue to attract high exploration interest in order to widen the supply base.

93. The dependency on supplies of minerals from outside sources has led some countries to the identification of strategic minerals, an imprecise term that embraces the concepts of criticality and vulnerability. At the national level, the criticality of a mineral depends on its contribution to the national economy and general physical well-being, and critical minerals may in some cases be vulnerable to interruptions of supply. In 1985, a report by the Office of Technology Assessment of the Congress of the United States of America noted that only three nations (South Africa, Zaire and the former USSR) account for over half of the world's production of chromium, cobalt, manganese and platinum group metals, which are essential in the production of high temperature alloys, steel and stainless steel, industrial and automotive catalysts, electronics and other applications that are critical to the United States economy and the national defence. 36/

94. A fuller knowledge of potential sources of supply is therefore likely to be of increasing interest to many countries.

95. A number of countries have participated in producing an International Strategic Minerals Inventory (recently renamed International Studies of Minerals Issues), which has produced valuable information on the identified resources of many commodities, mainly metals but also important non-metallic industrial minerals, such as phosphate and graphite. However, it has not proved possible to make estimates of undiscovered resources (see figure 2).

D. Availability of land for exploration

96. Population pressures world wide, and attendant environmental impacts are causing increasingly severe competition for land use, and there has also been a reaction against mining in some countries. The need to meet the global demand for mineral resources from the most efficient sources world wide is not readily appreciated either by local communities, whose lifestyle may be affected by major mining projects, or by national conservation movements. This is

especially the case if the demand is perceived to be the result of extravagant or wasteful consumption patterns with undesirable environmental impacts. It is therefore important that strategies to maintain supply be linked to effective strategies for moving to sustainable production and consumption patterns.

97. Such factors, related to population pressure and environmental impacts, can militate against the vigorous exploration programmes that will need to be pursued in the most prospective areas world wide if essential mineral supply is to be maintained. It must be recognized that only a relatively small proportion of continental terrains are highly prospective for each of the various metallic mineral deposit types. Such terrains need to be identified, and their mineral potential taken into account in determining needs for mineral exploration, both in a global context and within the context of an integrated approach to land-use planning. This will not be feasible unless a comprehensive information base is developed on mineral resource potential, that can be integrated with other land-use information.

E. Assessment of mineral resource potential

98. Terrains that are prospective for particular mineral deposit types have been called permissive tracts and their identification is the first step in the assessment of mineral potential and of unidentified resources. Such permissive tracts can be identified on the basis of geoscientific mapping programmes carried out by national geological surveys. In conjunction with information on mineral occurrences, such mapping permits qualitative estimates of prospectivity and resource potential. It provides the basis for assessment and investment in exploration by mining companies. Mineral maps and/or metallogenic maps can be produced as by-products of geological surveys. 37/

99. It is also desirable to assess not only the most likely geographic sources but also the quantities of undiscovered deposits in both the hypothetical and speculative categories. Hypothetical resources are those "that may reasonably be expected to exist in a known mining district or mineral province under known geological conditions, while speculative resources are those that may occur either in known types of deposits in a favourable geological setting where no discoveries have previously been made, or in yet unknown types of deposits that remain to be recognized". 38/ Both hypothetical and speculative sources contain deposits that are likely to be economic or marginally economic under current criteria.

100. Several approaches have been made to the quantitative assessment of undiscovered mineral resources. 39/ Most notably, a three-part method of quantitative assessment has been applied by the United States Geological Survey since 1975. Its original purpose was to provide quantitative resource information in a form consistent with an economic analysis so that mineral resource values could be compared with other competing uses of land. 40/ Such assessments are most reliable for relatively small geological provinces in which the mineral deposit geology is already well known.

101. More recently, there has been a proposal to make a national three-part assessment, to provide a consistent, usable minimum level of current

mineral-resource information, together with estimates of total undiscovered mineral endowment, for the entire United States. 41/ It was suggested that such an assessment is essential for ensuring that all domestic mineral resources will be considered in planning the optimum use of the State's public lands and for securing long-term mineral supplies from national and international sources.

102. As a first step in this programme, it was also proposed to carry out a two-year preliminary quantitative national assessment based on existing national data to produce maps showing the outlines of tracts that are permissive for the types of deposits concerned. Such a preliminary assessment would be of great value for planners in the United States, and similar assessments would be of even greater value in developing countries with substantial resource potential. Moreover, the value of all such national assessments would be greatly enhanced if they could be examined in the context of global potential and global resource needs.

103. However, it is unrealistic at present to propose a similar quantitative assessment world wide. In most countries, the level of geological knowledge is inadequate for assessments by this three-part methodology, and there are impediments to the acquisition of such knowledge, both in terms of expertise and financial resources. 42/

104. A more realistic global goal would be to produce maps delineating permissive tracts world wide, using internationally agreed criteria, which would involve only the first steps in the proposed United States preliminary assessment, namely:

(a) Compile existing data;

(b) Apply limited mineral-deposit models;

(c) Construct maps of delineated permissive tracts.

105. Such maps would provide the basis for iterative assessments of undiscovered resources as data became available. Although the assessments of individual tracts would generally be, at best, semi-quantitative, the global picture thus provided would allow much more realistic assessments of sustainability beyond the horizon currently provided by identified resources.

106. Of more immediate importance, such maps would assist the consideration of minerals issues within an integrated approach to land-use planning. They would allow the needs for mineral exploration and development to be assessed in relation to other land-use needs. Moreover, since perceived mineral resource potential has been identified as the most important single criterion for the international mining industry in assessing the investment environment for exploration, a global programme identifying permissive tracts world wide would be of great value in assisting the effective, efficient and socially harmonious operation of the industry.

107. For example, such a programme would assist local and national populations in appreciating the wider global interest in keeping the principal permissive tracts of the world open for exploration and development as far as possible, so

that the global endowment of mineral resources can be effectively managed and utilized.

108. It is important to distinguish between the scope of mineral exploration and the scope of mineral developments. It must be recognized that, although it is necessary to explore over large areas, this can largely be accomplished by non-intrusive techniques, such as aeromagnetic surveys, and exploration is not generally incompatible with other land uses. Mineral development per se, following successful exploration, will continue to affect only relatively small areas. If current best practice in integrating environmental and development concerns is implemented, 43/ the short-term environmental impacts of mining can be minimized within acceptable limits, and its long-term impacts can be made negligible. It also needs to be emphasized that, under appropriate environmental guidelines, the needs for exploration and development are not incompatible with other forms of land-use, including agriculture and national parks.

109. Accordingly, at its second session, the Committee on Natural Resources concluded that the United Nations could make a major contribution to the long-term management and sustainable development of mineral resources through developing a global knowledge base, at appropriate scales, of the potential for mineral resource exploration and development. 44/

Recommendation 3

110. In accordance with recommendations 1 and 2 (see paras. 66 and 73 above), it is recommended that a global knowledge base on mineral resource potential, especially the identification of permissive tracts be developed and integrated with other land information, so that the horizon of sustainability can be extended and land-use planning can properly take into account national and global needs for mineral exploration and development.

111. The Committee is aware that much of the information required is already being collected in many countries, and that a number of existing international organizations (both governmental and non-governmental) could assist in the development of such a global knowledge base. The World Bank has also recognized the importance of such information for developing countries. It is believed, therefore, that a global knowledge base could be developed at relatively low cost by building on existing efforts of many institutions at the national and regional levels. The United Nations needs to define the global mission and provide the necessary coordinating mechanisms. An advisory body is needed to set standards for organizations to follow in collecting and collating geoscientific information, including the development of globally consistent approaches to the definition of permissive tracts and the assessment of resource potential.

112. Countries with well-established geological surveys and mineral industries, as well as and those with existing international minerals programmes, can play leading roles in the development of such a programme at the regional level. The newly created agencies for mineral resources in the Central European countries could also play an immediate role. There will be a need to provide financial and technical assistance to some developing countries to carry out data

acquisition and interpretation; other countries, such as the countries of the former USSR, need substantial assistance to ensure that information gathered in the past on a confidential basis is not irrevocably lost and contributes to the global knowledge base.

113. Such a global knowledge base is clearly essential if the concept of sustainable consumption patterns is to be developed to take into account resource availability as well as environmental impacts. This is in accord with the objective established in chapter 40 of Agenda 21 to strengthen local, provincial, national and international capacity to collect and use information in decision-making processes (para. 40.5 (b)). Chapter 40 also recognizes the need to carry out inventories of environmental, resource and developmental data, and it suggests that data-collection activities need to be strengthened within the organs and organizations of the United Nations system, including, in the area of land resources (para. 40.8).

IV. CONCLUSION: REVIEW OF RECOMMENDATIONS

114. The actions proposed in recommendations 1, 2 and 3 (paras. 66, 73 and 110 above) are relatively non-controversial and low cost. Much of the information required is already being collected at national level. It is appropriate for the United Nations to assist in the management of global issues by coordinating the collection of information to provide a global framework for policy formulation at both the international and national levels.

115. The commission on mining and materials proposed under recommendation 1 (para. 66 above) could perhaps be appropriately placed in the Department for Development Support and Management Services, where it would provide direct support to the Committee in its advice to the Economic and Social Council, or alternatively in UNCTAD, where it could provide technical underpinning for UNCTAD's current brief.

116. The capacity to coordinate the activities identified in recommendations 2 and 3 (paras. 73 and 110 above) appears to lie principally in the Department for Development Support and Management Services, the principal operational arm of the United Nations Secretariat, and with the regional commissions. More specifically, the Division for Environment Management and Social Development provides a multidisciplinary approach in areas of natural resources, and provides support services to CNR; its Natural Resources, and Environment Planning and Management Branch has particular expertise in the minerals sector.

117. The Department has not hitherto engaged in such specific activities as those recommended above. However, in the course of its technical assistance activities the Department has participated in the creation of a number of national mineral inventories and geo-databases. The information and expertise developed during the execution of such projects could readily be applied to a coherent mineral-resource assessment programme, coordinated by the United Nations and designed to unite and standardize current independent and regional initiatives.

Notes

1/ Report of the United Nations Conference on Environment and Development, Rio de Janeiro, 3-14 June 1992, vol. I, Resolutions Adopted by the Conference (United Nations publication, Sales No. E.93.I.8 and corrigenda), resolution 1, annex II.

2/ See, for example, Preston Cloud, "Entropy, materials and posterity", Geologische Rundschau, vol. 66, No. 3 (1977).

3/ Our Common Future (World Commission on Environment and Development, 1987).

4/ See, for example, "Indicators of sustainable development for decision-making", report of a workshop held in Ghent, Belgium, 9 to 11 January 1995 (Belgium: Federal Planning Office).

5/ Mineral deposits are renewable on geological time-scales, and indeed some kinds of mineral deposits, such as those in major oceanic rift systems, are being formed at the present day. However, terrestrial deposits of the kinds and grades currently being mined are essentially non-renewable.

6/ See Crispin Tickell, "What we must do to save the planet", New Scientist (7 September 1991).

7/ See the Rio Follow-up at Regional Level: A Review of Major Regional Policy Implications of the Outcome of the United Nations Conference on Environment and Development (United Nations, Geneva, 1993).

8/ Report of the United Nations Conference on Environment and Development ..., annex I.

9/ The custom of including fossil fuels within a general definition of mineral resources is illustrated, for example, in International Mineral Development Source Book, J. F. McDivitt, ed. (Golden, Colorado: Forum for International Mineral Development, 1993). However, issues relating to fossil fuels are not within the formal mandate of the Committee on Natural Resources but within that of the Committee on New and Renewable Sources of Energy and on Energy for Development. Consequently, no recommendations are made in the present paper concerning fuel minerals. Nevertheless, some reference to fuel minerals is included because the broader issues of exploration and development in the mining sector encompass the fuel minerals, and because the issues of availability and environmental impacts of both metallic and industrial minerals are closely linked to energy use.

10/ Such as those of the Scientific Committee on Problems of the Environment of the International Council of Scientific Unions, notably in the fields of biogeochemical cycles, and health and ecotoxicology.

11/ See "Development, environment and mining: enhancing the contribution of the mineral industry to sustainable development", post-conference summary of

the International Conference on Development, Environment and Mining, Washington, D.C., 1-3 June 1994.

12/ See, for example, L. Arizpe, R. Costanza and W. Lutz, "Population and natural resource use", in An Agenda of Science for Environment and Development into the Twenty-first Century, J. C. I. Dooge et al., eds. (Cambridge University Press, 1992).

13/ See H. E. Daly and J. B. Cobb, Jr., For the Common Good: Redirecting the Economy toward Community, the Environment, and a Sustainable Future (Boston: Beacon Press, 1989); see also Agenda 21, chap. 4, paras. 4.10 and 4.11, which call for consideration of new concepts of economic growth less dependent on the Earth's finite resources.

14/ See, for example, data for the United States of America and Japan in F-W. Wellmer and M. Kürsten, "International perspective on mineral resources", Episodes (September 1992); fig. 12.

15/ See Wellmer and Kürsten, op. cit., fig. 10, showing a trend of gradually increasing consumption of base metals in industrialized countries between 1970 and 1990.

16/ See Wellmer and Kürsten, op. cit., fig. 9.

17/ See, for example, J. F. Bookout, "Two centuries of fossil fuel energy", Science, No. 253 (1989).

18/ See H. E. Daly, Steady State Economics (San Francisco: W. H. Freeman, 1977); see also P. Demeny, "Demography and the limits of growth", Population and Development Review, supplement No. 14 (1988).

19/ See B. J. Skinner, "Resources in the twenty-first century: can supplies meet needs?", paper presented at the World Natural Resources Colloquium, Twenty-eighth International Geological Congress, Washington, D.C., 1989.

20/ Estimate in Wellmer, personal communication (1994).

21/ See H. Schütz and S. Bringezu, "Major material flows in Germany", Fresenius Environmental Bulletin, vol. 2, No. 8 (1993); note also that water inputs amount to 730 tons per capita (mostly cooling water for power plants).

22/ See P. Gilding and G. Lawer, "Eco-competitiveness", in Management (April 1996); in addition, Agenda 21, para. 4.18, notes that reducing the amount of energy and materials used per unit in the production of goods and services can contribute both to the alleviation of environmental stress and to greater economic and industrial productivity and competitiveness.

23/ See Mineral Commodity Summaries 1995 (United States Department of the Interior: Bureau of Mines).

24/ See, for example, A. Kelly, "The future of metals", Minerals Industry International, No. 996 (1990).

25/ Reported in F. W. Wellmer, personal communication (1994).

26/ F. Hinterberger, S. Kranendonk, M. J. Welfens and F. Schmidt-Bleek, "Increasing resource productivity through eco-efficient services", Wuppertal Papers, No. 13 (May 1994).

27/ See, for example, W. G. B. Phillips, "Factors affecting the long-term availability of bulk minerals for the construction industry", in Resources and World Development (John Wiley and Sons, 1987).

28/ See "Mineral resources and sustainable development: a workshop", Technical Report, No. WF/94/12 (Keyworth, Nottingham: British Geological Survey, 1994).

29/ See P. J. Cook, "Societal trends and their impact on the coastal zone and adjacent seas", in Proceedings of the International Conference "Coastal Change 95" (Bordeaux: Bordomer/Intergovernmental Oceanographic Commission, 1995).

30/ See "International strategic minerals inventory summary report, 1984: phosphate", United States Geological Survey Circular, No. 930-C.

31/ See, for example, R. P. Sheldon, "Industrial minerals, with emphasis on phosphate rock", in Resources and World Development, op. cit.; Phosphate Deposits of the World, A. J. G. Northolt, R. P. Sheldon and D. F. Davidson, eds., vol. 2, Phosphate Rock Resources (Cambridge University Press, 1989); and Mineral Commodity Summaries 1995 (United States Department of the Interior: Bureau of Mines).

32/ The Commission noted, for example, the inputs provided from various sources, including an expert seminar on the theme "Sustainable consumption and production patterns" (Cambridge, Massachusetts, 18-20 December 1994); sponsored by the Massachusetts Institute of Technology and OECD.

33/ A. G. Darnley and others, "A global geochemical database for environmental and resource management: recommendations for international geochemical mapping", final report of IGCP Project 259, "Earth sciences 19" (UNESCO, 1995).

34/ See, for example, F-W. Wellmer and M. Kürsten, op. cit.

35/ See "Lead-time study: review of progress, 1993", International Strategic Minerals Inventory, Thirteenth Working Group Meeting (published by the United States Geological Survey; prepared as a cooperative effort among earth-science and mineral resource agencies of Australia, Germany, South Africa, the United Kingdom and the United States of America).

36/ See United States Congress, "Strategic materials: technologies to reduce United States import vulnerability" (Office of Technology Assessment, Washington, D.C., 1985).

37/ See A. Emberger, "Geological mapping and mineral maps", in International Mineral Development Source Book, J. F. McDivitt, ed. (Forum for International Mineral Development of the Colorado School of Mines, 1993).

38/ See "BMR refines its mineral resources classification system", Australian Mineral Industries Quarterly, vol. 36, No. 3 (1984).

39/ See, for example, J. P. Dorian and J. Zwartendyk, "Resource assessment methodologies and applications", Materials in Society, vol. 8, No. 4 (1984).

40/ See D. A. Singer, "Basic concepts in three-part quantitative assessments of undiscovered mineral resources", Non-Renewable Resources, vol. 2, No. 1 (1993).

41/ J. A. Briskey, Jr., "A proposed national mineral resource assessment", Non-Renewable Resources, vol. 1, No. 4 (1992).

42/ See Deverle P. Harris and others, "Evaluation of the United States Geological Survey's three-step assessment methodology", research report to the United States Geological Survey (1993).

43/ See, for example, the Berlin Guidelines adopted by the International Round-table on Mining and the Environment (Berlin, June 1991) (E/C.7/1993/10, annex I).

44/ See Official Records of the Economic and Social Council, 1994, Supplement No. 6 (E/1994/26).